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(54) **A matching member.**

(57) An acoustic matching member (3) for a sonic transducer is disclosed which comprises a solid material, for example a glass, in which a plurality of voids have been formed.

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A matching member

This invention relates to a transducer and more particularly to an acoustic matching member therefor.

There are a number of useful measurement applications that are conveniently achieved by sending and receiving ultrasonic signals in gases in the frequency range between 100KHz and 1MHz or above. At these high frequencies, the conventional construction of sound transducers employed at lower frequencies (eg audio frequencies) is impractical as the overall dimensions become very small.

The normal method of making high frequency ultrasonic transducers is to use a selected piece of piezo ceramic (eg Lead Zirconate Titanate or PZT) resonant at the required frequency. PZT is a hard, dense material of high acoustic impedance (approximately 3×10^7 in MKS units), while gases have very low acoustic impedance (of the order of 400 in the same units). PZT on its own gives very poor electro acoustic efficiency due to the large acoustic mismatch, even though this is improved somewhat by resonant operation.

Typically, the piezo ceramic element is a cylinder, whose circular end faces move in a piston-like manner in response to electrical stimulation of electrodes applied to these faces. The normal method for reducing the acoustic mismatch to gases is to apply an acoustic matching layer to the selected operational face of the PZT disc. This layer is a material of relatively low acoustic impedance whose thickness is one quarter of an acoustic wave length in the material at the chosen frequency of operation. This dimension results in a resonant action whereby (for sending) the small movements obtained at the face of the PZT cylinder are magnified considerably, and acceptable (though still now high) efficiency can be obtained. Criteria for acoustic-electric conversion (ie receiving) are the same as for electro-acoustic conversion (ie sending) and the same transducer may be used for both.

The efficiency attainable by this technique is limited entirely by the characteristics of available materials. An ideal material would have an acoustic impedance of the order of 10^5 and very low internal losses, and also must be stable, repeatable and practical for use. There are no hitherto known materials that meet all these criteria. Some common approximations to the ideal requirements are:

1. Silicone elastomers. This class of materials is commonly used and gives useful performance in many applications. Acoustic losses are low. Acoustic impedances down to about 7×10^5 can be attained. A significant drawback with these materials is a large variation of acoustic wavelength with temperature (typically 0.3%/K). This factor limits the range of operating temperatures over which correct reasonant matching is obtained.

2. Polymers generally. Many polymers give useful performance. acoustic impedance is higher than for silicones - down to 1.5×10^6 so overall efficiencies are lower, but reasonably stable materials can be found.

3. Liquids and gases. Examples in the literature may be found of the experimental use of multiple acoustic matching layers. Liquids have generally very low losses and acoustic impedances down to about 10^6. If a gas is compressed, its acoustic impedance rises directly with the compression ratio, and a captive volume of liquid or highly compressed, dense gas may be used as an acoustic matching layer. Such techniques are not practical for commercial application.

According to the invention in a first aspect there is provided an acoustic matching member for a transducer, the member comprising a material having a plurality of voids formed therein, the velocity of sound in the voided material in the direction of sound propagation of the member being substantially less than that for unvoided said material.

According to the invention in a second aspect, there is provided a method of forming an acoustic matching member for a transducer comprising the steps of forming the member from a material in which a plurality of voids have been introduced whereby the velocity of sound in the voided material is substantially less than that of the unvoided material in the direction of sound propagation of the member.

Such voids are preferably formed by compressing hollow microspheres under the application of heat to form an "aerated" material structure or by foaming molten material with a gas.

An embodiment of the invention will now be described by way of example with reference to the accompanying drawing which shows a PZT cylinder (1) with electrical connecting wires (2), to which a matching layer (3) is affixed. The direction of sound emission is indicated by arrow (4).

Bulk acoustic impedance is the product of density and bulk acoustic velocity. Acoustic velocity in turn is a function of bulk elastic modulus. These parameters may be artifically adapted in an otherwise unsuitable material to create a material with substantially improved characteristics. A preferred starting material is C-glass (soda-lime-borosilicate glass) which is stable and low loss, but has a very high acoustic impedance. The material can also be easily formed when heated and has a predictable

degree of softening with temperature. By arranging for the glass to be formed into a sponge structure with a very high proportion of voids, acoustic impedances down to 3×10^5 have been experimentally obtained.

Glass is readily available in the form of glass bubbles (hollow microspheres), used in diverse commercial applications such as syntactic foams and car body fillers and manufactured, for example, by Minnesota Mining and Manufacturing Company Inc. under the trade name 3M glass bubbles.

A very light glass sponge structure is easily achieved by heating the glass bubbles in a mould to a temperature where the glass is soft, and compressing by a specific volumetric ratio to join the bubbles together.

Acceptable processing conditions are, for example, at a temperature of 650°C approx. and a volumetric ratio of 1.5 to 2.5 to 1. With a suitable mould, the finished piece (2) is produced that may be applied to the PZT cylinder (1) without further adjustment.

For a given specification of glass bubbles and compression ratio, a repeatable result is obtained. For example glass bubbles with a starting density of $0.25g/cm^3$, compressed at a volumetric ratio of 2:1 produce a material having a propagation velocity (velocity of propagation of longitudinal bulk waves) of approximately 900m/s, compared with 5-6000m/s for unvoided glass. This gives an acoustic impedance of 4.5×10^5 compared with unvoided glass (ρ = 2.5) which has an acoustic impedance of approximately 14×10^6.

The resultant voided material also exhibits practically no variation in acoustic wavelength or bulk elastic modulus with temperature over the range of ambient temperatures.

As much of the material structure is formed by the voids between bubbles which communicate with the external surfaces (ie. not "closed cell"), it is usually necessary to seal the material surface against ingress of moisture etc. This can be achieved in various ways without seriously imparing the acoustic performance - for instance a thin layer of silicone elastomer or a thin layer of low melting point glass is satisfactory.

While, in the preferred embodiment described above, the material used is C-glass, this is not be construed as limitative and another glass or other non-crystalline material may be used.

Alternatively, a synthetics plastic material, for example a plastics resin or a metal, for example aluminium or titanium, may be employed. With resin, similar temperature dependent effects to those mentioned in the introduction will occur, although the invention does allow the velocity of sound propagation in the material to be adjusted. Furthermore, other methods of forming the acoustic matching member may be used, for example, by foaming the material to provide the necessary voids, these methods being particularly applicable for use with the plastics and metals mentioned above.

Claims

1. An acoustic matching member for a transducer comprising a material having a plurality of voids formed therein, the velocity of sound in the voided material in the direction of sound propagation of the member being substantially less than that for unvoided said material.

2. A member as claimed in claim 1 wherein at least some of the voids are interconnected.

3. A member as claimed in claim 1 wherein the material is in sponge form.

4. A member as claimed in any one of the preceding claims wherein the material is non-crystalline.

5. A member as claimed in claim 4 wherein the material is a glass.

6. A member as claimed in any one of the preceding claims wherein the bulk elastic modulus of the material remains substantially constant with respect to the range of ambient temperatures.

7. A member as claimed in any one of the preceding claims further comprising a moisture sealing layer enclosing the material.

8. A member as claimed in claim 7 wherein the sealing layer comprises a silicone elastomer.

9. A member as claimed in claim 7 wherein the sealing layer comprises a layer of glass.

10. An acoustic matching member substantially as hereinbefore described with reference to the accompanying drawing.

11. A transducer including an acoustic matching member as claimed in any one of the preceding claims.

12. A method of forming an acoustic matching member for an acoustic transducer comprising the steps of forming the member from a material in which a plurality of voids have been introduced whereby the velocity of sound in the voided material is substantially less than that of unvoided material in the direction of sound propagation of the member.

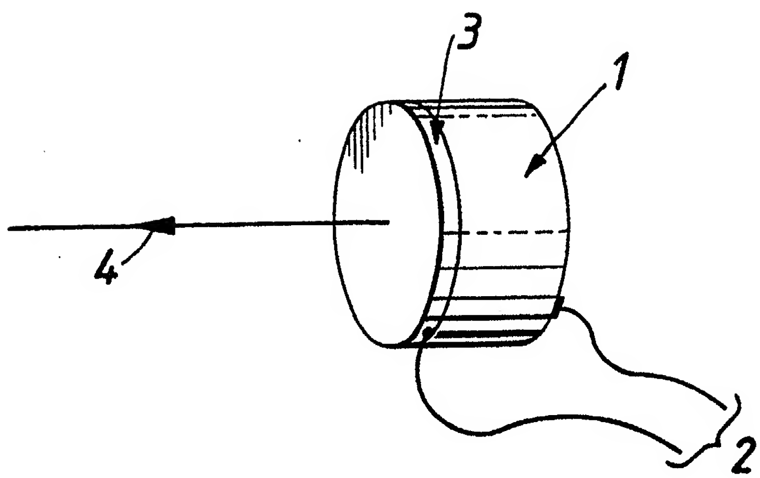
13. A method of forming an acoustic matching member as claimed in claim 12 comprising the steps of foaming the material in a molten state and casting the foamed material in a mould.

14. A method of forming an acoustic matching member as claimed in claim 12 comprising the steps of heating a plurality of hollow spheres of the material to a temperature at which the material softens and compressing the softened material in a

mould.

15. A method as claimed in claim 14 wherein the material is compressed at a start to finish volumetic ratio of 1.5 to 2.5 to 1.

16. A method of forming an acoustic matching member substantially as hereinbefore described with reference to the accompanying drawings.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